An Experimental Study Of Concrete Mixture Replacement Of Fine Aggregate With Plastic

[1] Mr. D.V.Shanmukesh, , [2] Mrs. Padadalam Lavanya, [3] Mr. M RVS.Gupta

[1,2,3,] Assistant Professor, Dadi Institute of Engineering &technology, Anakapalle, Visakhapatnam.

ABSTRACT

The objective of this research is to investigate the effectiveness of using waste plastic as fine aggregate replacement in concrete mixtures. The compressive and tensile strengths of various concrete specimens were tested to determine how the incorporation of recycled plastic as a replacement fine aggregate would affect the development of strength in the mixes. Six mixes were compared at replacement increments of 0%, 10%, 20%, 30% and 50% . All stages of plastic replacement showed a noticeable decrease in compressive strength. The 10% replacement level only showed a 15% loss of compressive strength at 21 days compared to the control. Despite being much weaker in compression, the tensile strength test showed that the 10%, 20% and 30% replacement increments were stronger in tension compared to the control.

I. INTRODUCTION

Concrete, one of the most common construction materials, requires a large amount of natural resources and energy. Natural resources used in concrete mixtures include lime stone, clay, sand, natural gravel, crushed stone, and water. With the rapid development in urban areas around the world in the recent years, our natural resources are depleting in an ever-increasing rate. Therefore, it is necessary to develop a new material that consumes less natural resources and energy in order to make our construction methods more sustainable. Many efforts have been made to study the use of waste/by product materials, such as fly ash, slag, silica fume, and natural pozzolan, to replace Portland cement in a concrete mixture. Studied effects of plastic in concrete mixtures as aggregate replacement on material properties. While the previous studies showed potential advantages of using plastics in concrete (e.g., light weight and low energy consumption), they also reported some disadvantages, such as decreases in compressive strength and flexural strength of plastic concrete mixtures with the increase of the plastic ratio in the mixtures. Furthermore, material properties of plastic concrete mixtures may vary depending on the type of plastics that is used in the mixtures. For this reason, it was of interest of this research to study effects of one type of plastics, high-density polyethylene, on concrete properties. This paper investigated the application of plastic on partial/full fine aggregate replacement for concrete mixtures.

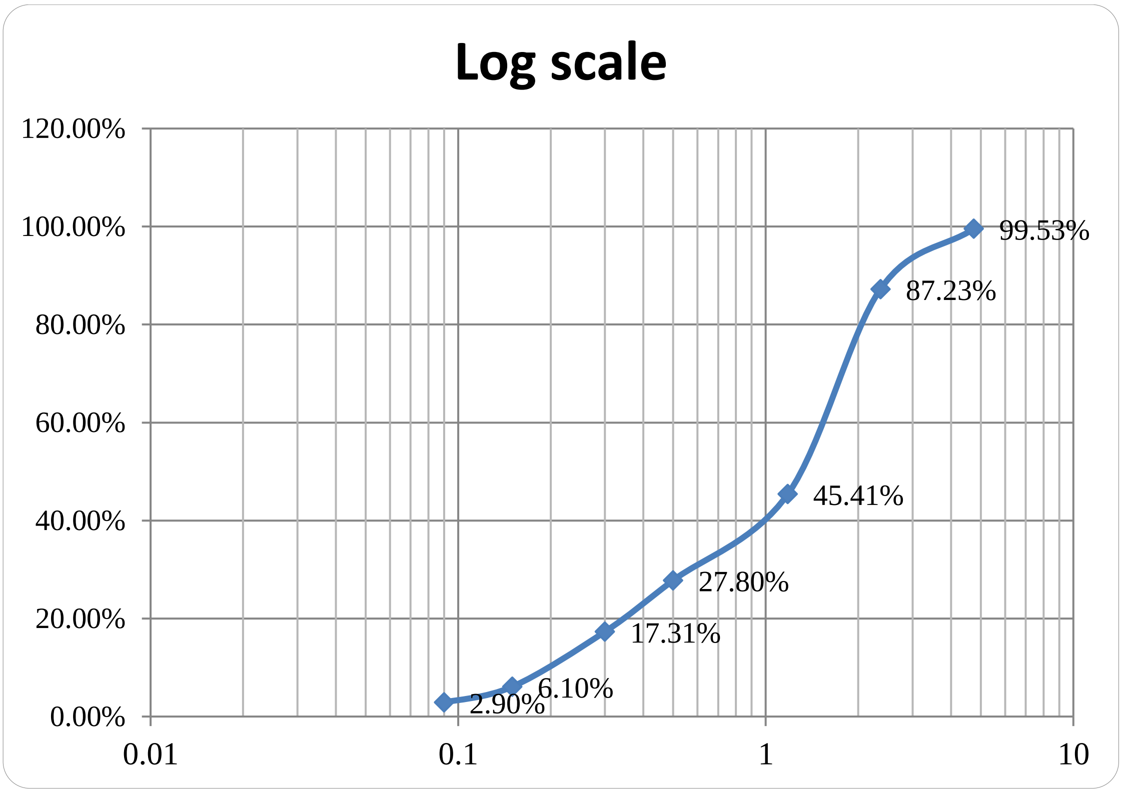
II. EXPERIMENTAL PROGRAM

A. Material Preparation Concrete materials used in this study included type I portland cement, river sand, 9.53mm crushed limestone, and water. Both sand and crushed limestone used in this study conformed to IS: 2386(Part-III)-1963 for concrete aggregates as fine and coarse aggregate was selected as the plastic for fine aggregate replacement in this study. The purpose for the experiment was to determine how best to incorporate construction waste materials back into concrete saving both energy and reducing the need to discard plastic waste into landfills. The experiment began by finding the gradation of the fine aggregate owing to that the gradation of sand could provide a baseline for the desired incorporation of recycled plastic as a fine aggregate replacement option. Sieve analysis was performed on a river sand sample to determine its gradation. The gradation test was conducted in accordance with

IS:2386(Part-III)-1963, and the results can be found below in Table 1. Initially, the goal was to mimic the sand gradation with the plastic gradation exactly; however, after a sieve analysis of the pulverized plastic was completed, this was deemed impracticable. As seen in Figure 1, the pulverized plastic has a much finer gradation than the sand. To accurately replace the gradation of the sand with the plastic, all of the plastic would have had to been sieved, weighted, and then remixed at the correct ratios. This process would have resulted in a lot of wasted plastic, which would have been counterproductive to the green initiative this project intended to propose.

S. NO.	IS Sieve Size	Weight Of Aggregate Retained (gram)			Average Of Weight Retained	Percentage of weight retained	Cumulative percentage retained	Percentage passing	Grading according to permissible % as per IS383 (grade I)
		T_1	T_2	T_3					
1	4.75mm	5	7	9	7	0.467%	0.467%	99.533%	90-100
2	2.36mm	185	183	186	184.67	12.31%	12.77%	87.23%	60-95
3	1.18mm	630	628	624	627.33	41.82%	54.59%	45.41%	30-70
4	500um	260	268	264	264	17.6%	72.197%	27.8%	16-34
5	300um	155	157	160	157.33	10.49%	82.687%	17.313%	5-20
6	150um	170	168	167	168.33	11.22%	93.907%	6.1%	0-10
7	90um	50	48	46	48	3.2%	97.107%	2.9%	-
8	pan	45	41	44	43.34	2.893%	100%	0%	-

Table-1: Particle Gradation (Fine)



X-axis: IS sieve size Y-axis: Percentage of Weight retained

Figure-1: Graphical Representation of Particle Gradation

The quantity of pellets added was based on the original gradation of the river sand. The design gradation determined for the tests can be found in Table 2.The percent of pellets added to the plastic was based on the percent retained on the sieves of the sand, i.e., the percent retained on the sieves from the sand gradation (Table 1) equals the percent retained on the #8 sieve for the plastic (Table 2).

Diameter(mm)	Percentage Retained(%)	Percentage Finer(%)
4.75	0	100
2.36	6.8	93.2
1.18	53.1	40.1
0.60	30.8	9.3
0.30	7.3	2.1
0.15	1.6	0.4
Pan	0.4	0

Table-2: Plastic gradation used in mix for design

B. Mix Design:

Using the aforementioned materials, mix proportions for one control mix and five experimental mixes were created. The control mix was designed with 0.5 water to cement ratio. The mix design was determined so that a reasonably concrete strength would be achieved to adequately determine the strength degradation induced by the increasing quantity of plastic. The experimental sample mixes utilized the same mix design with the exception of the fine aggregate. Mix designs for the control mix and the five experimental mixes with varying fine aggregate replacement levels are shown in Table 4.The water content of the actual batch weight was adjusted to account for the absorption of the aggregates. For the plastic, due to the susceptibility of plastic to heat, an absorption test requiring heating samples in an oven was difficult to perform. Based on the manufacturer specifications, the plastic had absorption between 0% and 0.1%. Therefore, for the purpose of this experiment, it was assumed that the had no absorption. Recycled white plastic resin was used for the experiment to amplify the potential reflectivity of the concrete. The plastic replaced the sand by volume. As mentioned previously, both the plastic and the sand were in a state of 0% absorption. Therefore, as the volume of sand was reduced and plastic added, the water content in the sample mixes did not need to be adjusted.

Material	0%	10%	20%	30%	40%	50%
CA	989.14	1098	1098	1098	1098	1098
FA	938	829	746	663	580	414
CEMENT	462.2	307	307	307	307	307
WATER	208	153	153	153	153	153
PLASTIC	0	10	14	27	41	68

Table-3: Mix Proportionate

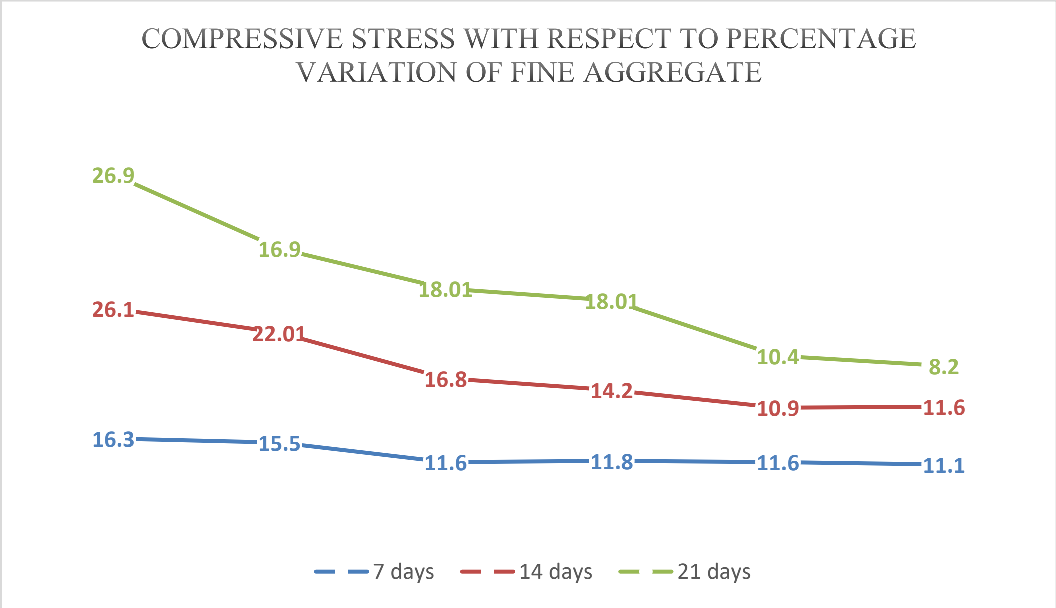
C. Test Procedures:

1. Compression test:

Percetage Replaced	07 Days	14 Days	21 days
0	16.3	26.1	26.9
10	15.5	22.01	16.9
20	11.6	16.8	18.01
30	11.8	14.2	12.9
40	11.6	10.9	10.4
50	11.1	11.6	8.2

Table-4: Compressive stress for the various days.

- **All the values are related to Compressive stress with units as N/mm^2.**



X-axis: Percentage of Replacement Y-axis: Compressive stress in N/mm^2

Figure-2: Graphical Representation of Compressive stress and Percentage Varation

D. Split Tensile Tests:

The cylinders were used for splitting tensile tests as experimental samples. The specimens were initially cured for twenty four hours and then placed in a water tank and cured for twenty one days. The cylinder was cut in half and the splitting tensile strength was performed on both specimens.The split-cylinder test showed a different result as compared to that of the compression tests, i.e., the compression tests showed a loss of strength with the increase of plastic while the split-cylinder tests Showed the opposite. As can be seen in Table 5, the control batch was weaker in tension than the 10%, 20% and 30% replacement mixes. Even the 30% replacement mix which was over 50% weaker in Compression , was 2% stronger in splitting tensile strength. It appeared that the addition of plastic caused fundamental changes the way that concrete behaved. Determining the optimum level of plastic replacement of the fine aggregate to attain the greatest tensile strength would require additional research and testing. The optimum amount of plastic cannot be directly interpolated because the tensile strength is dependent on two distinct variables: the compressive strength of the concrete and the amount of plastic in the mix. Additional study will be necessary to determine how each of the variables affect the tensile strength.

Percetage Replaced	Split Tensile test
0	3.25
10	3.4
20	3.8
30	3.3
40	3.05
50	2.8

Table-4: Split Tensile test for the various Percentages.

CONCLUSIONS:

The following conclusions can be drawn from this research study:

1. The temperature of the fresh concrete containing the plastic was comparable to that of the ordinary concrete.
2. The air content of the test samples increased with an increase in the percent replacement. The increase in air content was more significant when the percent replacement is greater than 30%.
3. Owing to the expansion caused by the plastic within the concrete, the slump test results could not be used as an indicator for the workability of concrete containing the plastic used in this study. For the materials used in this study, the workability of concrete decreased significantly for specimens with the plastic replacement level greater than 10%.
4. As expected, the unit weight of concrete decreased with an increase in the percent replacement owing to the light weight property of the plastic and the increase of air content due to the plastic replacement.
5. As the percent replacement increased, the compressive strength of the concrete decreased. More than 50% strength loss was observed for specimens with the percent replacement beyond 30%.
6. The 10%, 20%, and 30% replacement samples exhibited higher splitting tensile strength than that of observed for the specimens with percent replacement greater than or equal to 50%. The results suggested that a proper percentage of fine aggregate replaced by the plastic may be beneficial to tensile strength development.
7. The increase in the percent replacement increases the air content of the concrete, inhibiting the transfer of heat through the slab.

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